Continuation Proposal: to the TAMU Turbomachinery Research Consortium

MEASUREMENT OF LEAKAGE AND DYNAMIC FORCE COEFFICIENTS IN A POCKET DAMPER SEAL & A LABYRINTH SEAL SUPPLIED WITH A WET GAS

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SIGNIFICANCE

Developments in centrifugal compressors call for wet gas operation as subsea factories must handle two-phase flows with a liquid volume fraction (LVF) as high as 5%. The issue of a liquid trapped induced rotordynamic instability challenges wet gas compressor operation. Recall that Vannini et al. in 2014 [1] report a severe sub synchronous rotor vibration (SSV) at 0.45X in a single stage centrifugal compressor whose labyrinth seals (LS) operated with a 3% LVF wet gas. Replacing the LS with a pocket damper seal (PDS) successfully reduced the magnitude of SSV [2]. PDSs [3] offer large amounts of damping and an enhanced rotor stability under wet gas operation; hence then their selection in a liquid tolerant (wet gas) compression system.

Funded by TRC, Turbo Lab faculty and students [4-6] completed measurements of leakage and identified dynamic force coefficients for low-pressure and high-pressure PDS supplied with a wet gas. Leakage data in [6] appears to be in error. Presently, there is a need to quantify leakage and force coefficients for a *wet* gas PDS vis-à-vis a *wet* gas LS, both with identical clearance, cavity number and length, and in order to further validate the predictive bulk-flow model under development with TRC funds, see [7].

EXPERIMENTS ON TWO WET GAS PDSs at the TURBO LAB

Fig. 1 shows the TRC *wet* seal test rig comprising a seal and housing supported by four elastic rods tied to a rigid base. Two rigidly mounted electromagnetic shakers (± 445 N) excite the housing via long stingers to produce dynamic motions for the identification of force coefficients.

In 2018-2019, experiments were conducted with a fully partitioned PDS (D = 127 mm, L = 48 mm, clearance C_r = 0.18 mm) [4] and a novel stepped shaft PDS [5] supplied with a mixture made of ISO-VG-10 oil and air. Fig. 2 displays a photograph and a cut view of the test PD having four axial blades and eight pockets. The mixture supply pressure ranged from 1.1 bar to 3.2 bar and the shaft speed was 6,000 rpm (40 m/s surface speed). Technical reports TRC-SEAL-03-18 [4] and TRC-SEAL-02-19 [5] detail the experimental procedure, data analysis, and findings for the two PDSs, respectively.

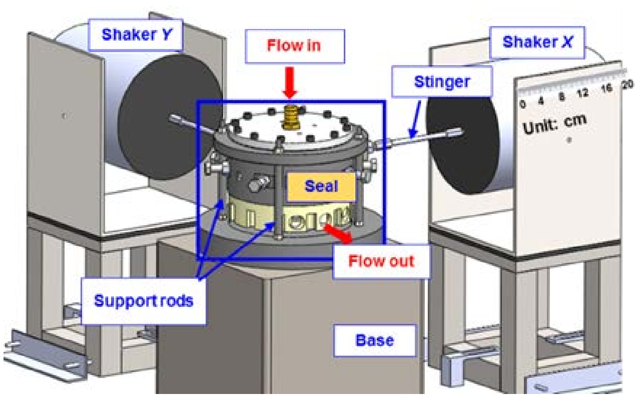

Fig. 1 TRC Wet gas seal test rig.

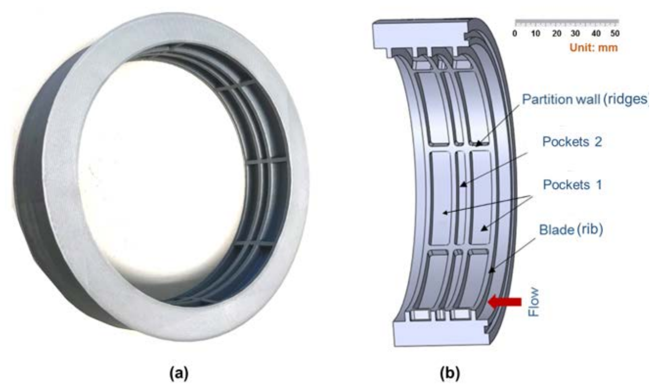

Fig. 2 (a) Photograph of test pocket damper seal (PDS), (b) Cut view of fully portioned PDS.

PROPOSED WORK 2020-2021

The proposed work aims to further quantify the performance of a PDS and a LS with similar dimensions and supplied with an oil in gas mixture, i.e. a *wet* gas. The ultimate goal is to quantify differences in performance and to provide data for model validation.

Table 1 lists the geometry for the existing PDS [4] and the LS (to be constructed). The two seals have similar dimensions but for the blade width and cavity width. Overall length is the same *L*=48 mm. *XL*LABY® predicts the same leakage for both seals (PDS and LS). The leakage for the two seals supplied with a *wet* gas still await tests.

Table 1. Geometry dimension of a four-blade PDS [4] and a tooth-on-stator labyrinth seal.

Length, L	48 mm	Diameter, D	127 mm
Clearance, C_r	0.18 mm	Pocket and Cavity depth	4.8 mm
Pocket & cavity width	10.5 mm / 4.8 mm	LS cavity width	11.6 mm
PDS Rib width, W_T	2.5 mm	LS Tip thickness, W_T	0.3 mm

Experiments with both seals will be conducted at a shaft speeds of 3 and 6 krpm (ΩR = 40 m/s), supply pressure to 5 bar (absolute), and an inlet gas volume fraction (GVF) from 90 to 100%. Dynamic loads exerted on the seal housing with a single frequency (10 Hz - 200 Hz, in steps of 10 Hz) will serve to identify the system complex dynamic stiffness matrix and frequency dependent force coefficients. Specific tasks include:

(1) Manufacture a labyrinth seal with similar dimension to the pocket damper seal in [4].

(2) Measure leakage for both seals supplied with a mixture, inlet GVF (90% to 100%), supply pressure to 4 bar, and two shaft speeds.

(3) For both seals, conduct dynamic load tests and identify frequency dependent force coefficients.

The test results will be a reference for the experimentally benchmarked design of ubiquitous LSs and PDSs. The test data is most valuable for neck-ring seals in impellers of wet gas compressors.

BUDGET FROM TRC FOR 2020-2021

Support for graduate student (20 h/week) x $ 2,200 x 12 months		$ 26,400
Fringe benefits (2.3%) and medical insurance ($210/month) x 12 months		$ 3,265
Tuition & fees three semesters		$ 16,728
Test rig – manufacturing labyrinth seal		$ 3,500
Test rig - operation – ancillary (miscellaneous)		$ 728
	Total Cost:	**$ 50,000**

REFERENCES

[1] Vannini, G, Bertoneri, M., Del Vescovo, G., Wilcox, M., 2014, “Centrifugal Compressor Rotordynamics in Wet Gas Conditions,” Proc. of the Turbomachinery & Pump Symposium, September 22-25, Houston, TX, pp. 201-220. Available electronically from http: / /hdl .handle .net /1969 .1 /162697.

[2] Vannini, G., Bertoneri, M., Nielsen, K. K, Ludiciani, P., and Stronach, R., 2016, “Experimental Results and Computational Fluid Dynamics Simulations of Labyrinth and Pocket Damper Seals for Wet Gas Compression,” ASME J. Eng. Gas Turbines Power, **138**(5), pp. 052501.

[3] Vance, J. M„ and Schultz, R. R., 1993, “A New Damper Seal for Turbomachinery,” ASME Proc. of 14th Biennial Conference on Mechanical Vibration and Noise, Vibration of Rotating Systems, **60**, pp 139-148.

[4] Yang, J., San Andrés, L., and Lu, X., 2018, “A CFD for Prediction of Leakage and Dynamic Force Coefficients of in Pocket Damper Seal: From Gas to a Wet Gas,” TRC-SEAL-03-18, Turbomachinery Research Consortium (TRC) Progress Report.

[5] Yang, J., San Andrés, L., and Lu, X., 2019, “On the Leakage and Dynamic Force Coefficients of a Novel Stepped Shaft Pocket Damper Seal: Experimental and Numerical Results,” TRC-SEAL-02-19, Turbomachinery Research Consortium (TRC) Progress Report.

[6] Delgado, A., and Thiele, J., 2019, “Rotordynamic Characteristics of Fully Partitioned Pocket Damper Seal,” Turbomachinery Research Consortium (TRC) Progress Report.

[7] San Andrés, L., and Yang, J., 2020, “A Simple Two-Phase Bulk-Flow Model for Prediction of Force Coefficients in Wet Gas Labyrinth Seals and Pocket Damper Seals,” TRC-SEAL-03-2020, Turbomachinery Research Consortium (TRC) Progress Report.